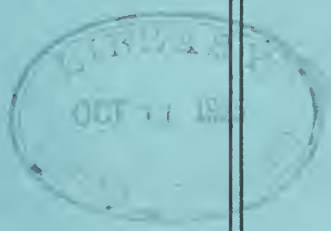
North American Council on Fishery Investigations

PROCEEDINGS 1931-1933

No. 2



OTTAWA
J. O. PATENAUDE, I.S.O.
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1935

North American Council on Fishery Investigations

PROCEEDINGS 1931-1933

No. 2

OTTAWA
J. O. PATENAUDE, I.S.O.
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1935

NORTH AMERICAN COUNCIL ON FISHERY INVESTIGATIONS

PROCEEDINGS 1931-1933

No. 2

The first issue of the Proceedings of this council appeared in 1932 and covered the period 1921-1930. It is planned for the present and following issues to cover in each case a three-year period. While previously there had been two meetings each year, beginning in 1929 there has been merely an annual meeting held in the autumn. Nevertheless, with increase in the extent of the investigations carried on by the various countries and reviewed by the council, there has developed the need of increasing the length of each meeting to two days in place of one.

During the period 1931-1933 Canada, France, Newfoundland and the United States were the countries represented on the council. Although France proved unable to be represented at the meetings, contact was maintained. The outstanding feature during the period was the initiation by Newfoundland (through its Fishery Research Commission) of a comprehensive investigation of the waters off its coasts and of the fisheries therein.

The investigations that have had the benefit of the common consideration that the meetings of the council permit are herein described separately for each country, as in the first issue of the Proceedings. However, in the case of Fishery Statistics and Hydrography there has been such definite co-operative work of a general character as to necessitate general accounts of the activities in these two fields. Also, the United States and Canada have carried on under an international commission a joint investigation of the fisheries of the Passamaquoddy region as to their being possibly jeopardized by proposed tidal dams, and a separate account is given of this co-operative effort.

2456—1½

REGULAR MEETINGS OF THE COUNCIL

No.	Place	Date	Members and Advisers Present				
			Canada	France	Newfoundland	United States	Int. Pass. Fish. Comm.[3]
18	Ottawa, Canada	Sept 29-30 1931	W. A. Found J. P. McMurrich A. G. Huntsman A. W. H. Needler[2] H. F. S. Paisley[2]		H. Thompson	H. O'Malley H. B. Bigelow[1] Elmer Higgins O. E. Sette[2]	C. J. Fish[2] M. Graham[2] H. H. Gran[2]
19	Washington, U.S.A.	Oct 20-21 1932	W. A. Found J. P. McMurrich A. G. Huntsman H. F. S. Paisley[2]		H. Thompson	H. O'Malley H. B. Bigelow[1] Elmer Higgins L. Radcliffe[2] O. E. Sette[2] W. C. Herrington[2] R. H. Fiedler[2]	C. J. Fish[2] M. Graham[2]
20	St. Andrews, N.B., Canada	Sept 13-14 1933	W. A. Found J. P. McMurrich A. G. Huntsman A. Vachon[2] A. H. Whitman[2] P. Cox[2] A. H. Leim[2] A. W. H. Needler[2] R. A. McKenzie[2] V. D. Vladykov[2] H. B. Hachey[2] H. I. Battle[2] W. H. Johnson[2] H. F. S. Paisley[2] A. A. Blair[2]		H. Thompson	H. B. Bigelow[1] Elmer Higgins O. E. Sette[2] C. Iselin, Jr.[2] W. C. Herrington[2]	E. E. Watson[2]

[1] Chairman. [2] Technical advisers. [3] International Passamaquoddy Fisheries Commission.

CO-OPERATION WITH INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

Early in its history the council approved the establishment of informal contacts with the International Council for the Exploration of the Sea (Proc. 1921-1930, p. 6). Closer, though still informal, relations between these two international bodies were established through the attendance of the chairman of the North American Council at the annual meeting of the International Council in Copenhagen in March, 1931, when, after presentation of an account of the activities of the North American Council, the International Council passed the following resolution:—

"The Council has heard with great interest the account given by Dr. H. B. Bigelow, Director of the Woods Hole Oceanographical Institute, of his plans for the investigations of the North Atlantic, particularly in its western part. It welcomes this important new development, and considers the moment opportune to enter into close co-operation both with the Woods Hole Oceanographical Institute and with the North American Council on Fisheries Investigations, believing that such co-operation will be fertile in results. It is of opinion that effective co-operation can best be achieved by close personal touch between the workers and accordingly invites representatives of both bodies to take part regularly in its deliberations, in order to arrive at unity of plan and methods in the study of those fundamental problems which are similar or identical on both sides of the Atlantic."

As a result of conferences at the time, informal agreement was reached that the Woods Hole Oceanographic Institution would carry out periodical surveys in the Northwestern Atlantic, the dates to conform with the quarterly cruises formerly carried out by the International Council. It was also recommended that co-operative studies of the fluctuations in abundance of food fishes common to the two sides of the North Atlantic, in relation to the factors in the environment, should be initiated as soon as feasible.

This closer co-operation between investigators on the two sides of the North Atlantic was approved, at the 18th meeting of the North American Council, in the following resolution:—

"The North American Council desires to express its appreciation of the invitation from the International Council, conveyed by its President, that the North American Council should be regularly represented at its annual meetings. The North American Council resolves that hereafter, when possible, a representative will attend the meetings of the International Council in alternate years, and hopes that representatives of that body may similarly attend the meetings of the North American Council. Many important problems are common to the two organizations and call for conjoint discussion and co-operation, which may be facilitated by such an interchange of representatives."

It was not possible for any of the North American members to meet with the International Council in 1932. But in May, 1933, the chairman attended the annual meeting at Paris, bringing, as before, a report on the various lines of investigation carried out by the North American Council. At this meeting, resolutions were passed approving closer co-operation between the two councils along the following lines:

1. That the International Council are prepared to include a summary of the work of the North American Council annually in their Rapports Atlantique.

2. The International Council continues to invite the representatives of the North American Council to attend its annual meetings.

An arrangement was also made for inclusion in the Hydrographic Bulletin of the International Council of serial observations on temperature, salinity and chemical characteristics of the waters of the Western Atlantic. And the Woods Hole Oceanographic Institution commenced publication of its station data in this way in 1932.

At the 20th meeting of the North American Council it was voted to send a digest of its activities for the year to the International Council for publication as above, with appreciation of the invitations extended.

INTERNATIONAL PASSAMAQUODDY INVESTIGATIONS

The proceedings for 1921-1930 contain a résumé of the deliberations of the council regarding the probable effects, on the local fisheries, of damming Passamaquoddy and Cobscook bays. Acting on the council's recommendations, the governments of the United States and of Canada, organized in 1931, an International Commission to carry on further investigations, funds having been appropriated for the purpose.

The personnel of the commission was, for Canada, Mr. W. A. Found and Dr. A. G. Huntsman; for the United States, Mr. H. O'Malley and Mr. O. E. Sette. Field work was carried on from July, 1931, until October, 1932. The

scientific personnel consisted of Dr. E. E. Watson, hydrographer; Dr. H. H. Gran, phytoplanktologist; Mr. Michael Graham, ichthyologist; Dr. C. J. Fish, zooplanktologist and executive secretary; Mr. T. Braarud, assistant phytoplanktologist; and Dr. M. W. Johnson, assistant zooplanktologist. Three vessels were utilized, the *Prince* and the *Pelican* assigned by the Canadian and American governments respectively, and the *Nova IV* chartered from December 1, 1931, until June 30, 1932. The scientific staff had its headquarters partly at the Atlantic Biological Station at St. Andrews, and partly at the Woods Hole Oceanographic Institution at Woods Hole.

Members of the scientific staff presented interim accounts of the progress of investigations to the council at Ottawa, September 29-30, 1931, and Washington, October 20-21, 1932. The field work was completed in the summer of 1933, and at the 20th meeting of the council, Doctors Watson, Fish, Mr. Braarud, and Dr. Huntsman for Mr. Graham, presented summaries of the work done. This included a general survey of the hydrography of the whole bay of Fundy south to Brier island and west to Mt. Desert, covering different times of the year. Eight hundred water samples for quantitative measurement of phytoplankton were collected at 156 stations in the bay of Fundy and the gulf of Maine in September, 1931, and from March to September, 1932, with correlation between plankton content and environmental factors of temperature, salinity, oxygen, phosphate and nitrate. Data on monthly radiation, and measurements of turbidity by means of microphotographs of centrifuged water samples were used for estimation of light conditions in the water. Eight hundred and thirty-eight collections of zooplankton were made, July, 1931, to September, 1932, on thirty-two plankton cruises in the bay of Fundy, and gulf of Maine west to Casco bay, with special stations on Georges bank and in the bays along the coasts of Maine, New Brunswick and Nova Scotia. Chief items in the herring studies were the mapping, by tow nettings, of the distribution of larvae at a great number of stations at different seasons, and analyses of catch records at different localities along the coast in relation to environmental factors and to the supply of planktonic food.

The final report was presented to the two governments in October, 1933, conclusions being as follows:—

Effect on the Region outside of the Dams.

"The physical effects of the present mixing mechanism appear to be local and although the construction of the dams would influence the hydrographic conditions in the passages, it is not expected that their influence would extend far into or beyond the Outer Quoddy Region.

"The influence of this local mixing on the supply of nutrient salts in the surface layers, where they are available for plant production, is almost entirely confined to the Quoddy Region. The conditions existing over the greater part of the Bay of Fundy appear to result from other factors, which would not be influenced by the dams. It is not considered that the construction of the dams would have an appreciable effect upon the production of plant life outside of the Quoddy Region.

"The rich fishery in the Quoddy Region is not due to a localized abundance of zooplankton. The zooplankton supply which supports the herring population outside of Passamaquoddy bay in summer (and is found within the bay in winter) is considered to be mainly produced in areas beyond the influence of

the Quoddy mixing mechanism and transported passively by ocean circulation into the region. Any influence of the proposed dams upon this supply would probably be insignificant.

" A sure forecast of the effect of the proposed dams on the fishery requires more comprehensive and more detailed knowledge of the biology of the herring than is available at present. The researches do, however, lead to some relevant conclusions.

"The herring population is produced beyond the influence of local mixing and no way has been foreseen by which the dams would render the Outer Quoddy Region or the bay of Fundy less favourable to the existence of herring arriving from elsewhere.

"The effect upon the availability of herring is likely to be considerable. Many changes in the set of the tidal streams may be expected, and probably every little change would have an effect on the fishery of nearby weirs. Some weirs would be made richer, some poorer. It cannot be foretold whether the total effect of disturbance of tidal streams on capture outside of the dams would be deleterious or not.

" There appears little probability of the proposed dams affecting the sardine fishery along the coast of Maine or even seriously at Grand Manan."

Effect on the Region Inside of the Dams.

" The herring fishery inside of Passamaquoddy bay would almost certainly be reduced to negligible proportions.

(Signed): Charles J. Fish
M. W. Johnson
Trygve Braarud
E. E. Watson
Michael Graham
H. H. Gran."

FISHERY STATISTICS

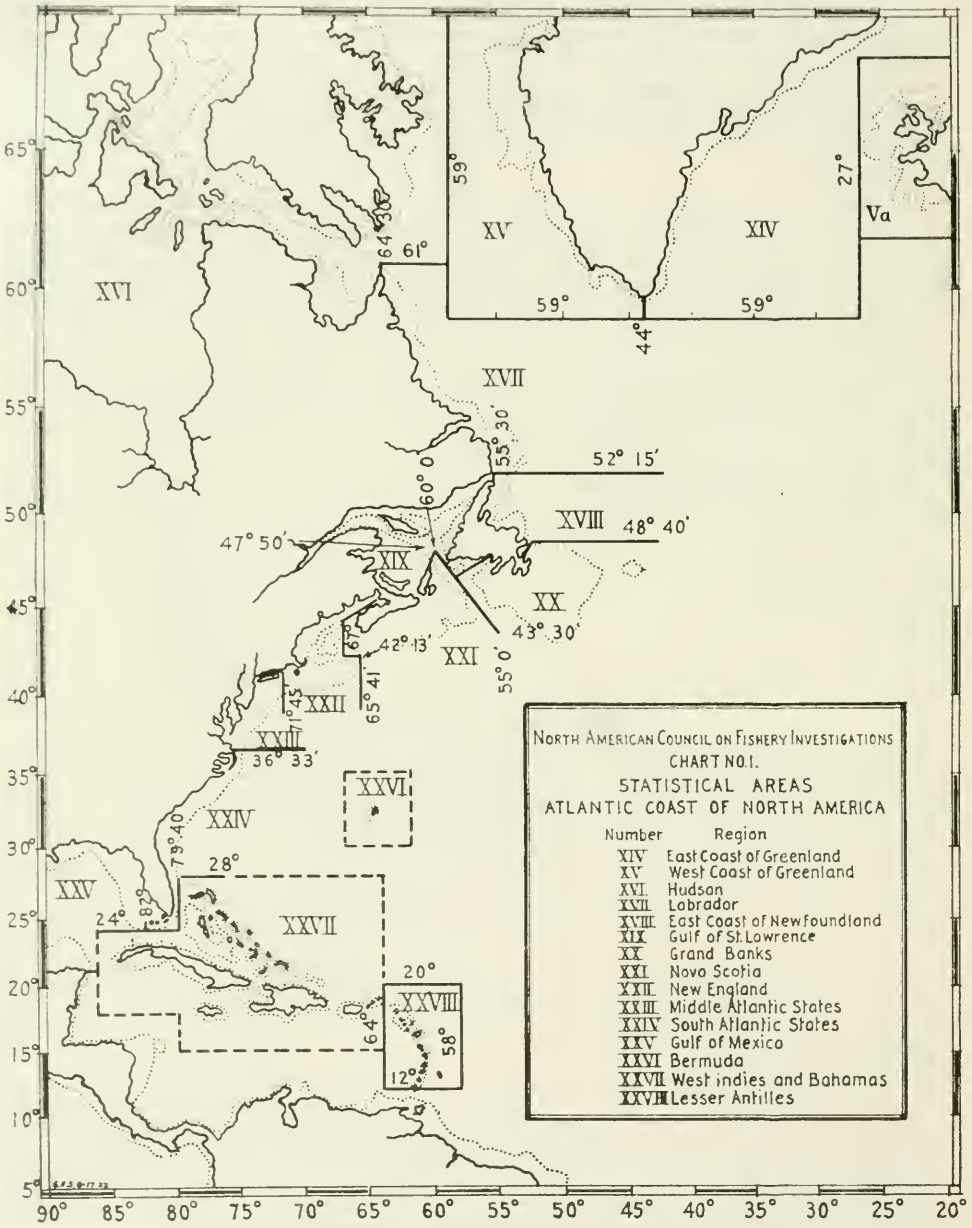
Recognizing the importance of suitable statistics to scientific investigations on the fisheries, the council has from time to time designated committees to study the various problems relating thereto. Development of a suitable plan of regional separation of statistics and of having statistics reported on a uniform basis (as concerns the state of preparation represented by the numerical quantities) occupied the major portion of the committees' deliberations. Other problems relating to the usefulness of statistics for biological purposes have also received their attention, and at the 18th meeting of the council the then standing committee reported the results of studies which were adopted by the council in the following form:—

" At the meeting of the Committee on Statistics of the North American Council on Fishery Investigations, held at Ottawa on September 29th and 30th, 1931, it was agreed that the publications dealing with general statistics of the catches of commercially valuable fishes are not in all cases as complete or in such a form as is to be desired. It was recommended that each adherent country should in publishing its statistics of catches pay special attention to the following principles:

" 1. The statistics should include the total catches made by the fishermen of each country in Western Atlantic waters, and where it is impossible to have complete statistics, to state wherein and to what extent the statistics as published are incomplete.

" 2. The statistics should be given for each species of fish separately.

"3. The data should preferably refer to the fresh fish as caught, i.e., before dressing. Where this is impossible, each country should include information and factors making it possible to convert its data to a fresh fish basis.



"4. To the utmost possible extent the statistics should be subdivided under the headings of the particular fishing grounds or inshore areas in which the catches are made. The areas demarcated on the accompanying chart (approved by the council) are suggested as the basis for minimum subdivision.

"5. Means of assessing the actual fishing effort should be supplied. Such means should include the following:—

(*a*) Classification of the catches under the heading of the gear with which they were made.

(*b*) The numbers of fishing craft (of various types) and the fishermen and of the quantity and types of the gears used in securing the subdivisions of the catches listed under item (*a*).

"6. It is desirable that statistics should be published and circulated at regular intervals and as soon as possible after their collection.

"7. So that the more immediate uses of the statistics may be realized, it is desirable that interim summaries be exchanged between the appropriate officials of the various countries.

"8. For the fuller interpretation of the complete commercial statistics, each country should collect in such detail as may be practicable data on representative portions of the various types of fishery. Such data should include accurate records of the fishing effort and of the quantity and length composition of the catches."

Following the adoption of these principles by the council, the statistics published by Canada and the United States have been using the regional designations recommended in Item 4 of the above report, and have contained supplementary statements providing the information designated in Item 3.

In addition to its general consideration of fishery statistics, the council has encouraged the compilation of comprehensive statistics on the particular species that are subject to international exploitation. Such reports on the cod and the haddock have already been reported. At the 20th meeting of the council a report on statistics of the mackerel fishery was submitted to and approved by the council. It has since been published as follows: *Statistics of the mackerel fishery off the East Coast of North America, 1804 to 1930. By Oscar E. Sette and A. W. H. Needler, Bureau of Fisheries, Investigational Report No. 19, 48 pp., Washington, 1934.* Similar reports on pollock and halibut are in preparation; also the matter of bringing up to date the former reports on cod and haddock.

HYDROGRAPHY

At its 1931 meeting in Ottawa the council resolved that in view of the primary importance of water conditions upon the course of the various fisheries it was desirable that all relevant information be communicated promptly to a centre for the purposes of collation and re-issue where desirable. Woods Hole Oceanographic Institution was suggested as a centre, but intimated that it was unable to undertake the work; whereupon, at the 1932 meeting in Washington, the Newfoundland laboratory was selected as the centre, and the following hydrographic committee was appointed, with power to add to its numbers:—

Harold Thompson (Newfoundland)
H. B. Hachey (Canada)
W. C. Herrington (U.S.A.)

It was agreed that physical data from the northwest Atlantic that are likely to prove of direct value to the study of International Fisheries should be assembled at one centre (Newfoundland). In accordance with this decision the several countries contributed, in 1933 and 1934, data for the Labrador and Newfoundland —Grand Bank regions; the Nova Scotian sector; the bay of Fundy—gulf of Maine region and the coastal region south thereof; and the Atlantic basin between the American coast and Bermuda. These data may be expected to yield informa-

tion regarding the position and the amount of ice in the northernmost sector; the extent of the southerly extension of the Labrador and Cape Breton currents; the physical characteristics from year to year of the water on the Banks; and the limits of the deep-lying water of 10-11° C. temperature along the continental edge of the United States coast. The applied study of such information in relation to the results achieved in the fisheries should ultimately lead to valuable correlations, and possibly aid in providing the basis of a prediction service.

The data primarily requested are temperature and salinity readings taken within 400 miles of the coast and within 400 metres of the surface; also observations of important and obvious deviations from the normal—e.g., the location of bodies of unusually warm or cold water, unusual distribution of ice, etc.

From the Newfoundland standpoint, for example, such data are valuable to supplement the hydrographic work done by that country. Thus the Canadian information enables an estimate to be made of the southerly extension of the Gaspe and Cape Breton currents, themselves probably Arctic in origin and capable of correlation with the Labrador current. The data promptly turned in by the International Ice Patrol afford early indications of the conditions off Grand Bank and of the position of the ice. The investigations made from Woods Hole are capable of less direct application, but afford information relative to the position of the deep-lying body of water of 10-11°C. east of the continental shelf off the Middle Atlantic and New England states. Here the squid, which is of such great importance as bait in the Newfoundland fisheries, but whose life history is not well known, is considered by some to breed. In like manner the data obtained by Newfoundland is of direct interest to Canada and the United States.

At the 1934 meeting of the council at Halifax it was decided to devote particular attention to obtaining consecutive and representative physical data from the whole continental slope off the North American coast. It is now clearly realized that such data are of paramount importance in order that an understanding may be reached of the fluctuations taking place in the physical conditions on the fishing grounds situated between the slope and the coast, and therefore of the fluctuations in the fisheries themselves. Arrangements will be made for international action to ensure the collection of such data, which will be handled by the Woods Hole Oceanographic Institution, and will be studied in conjunction with the corresponding data assembled by the European International Council for the northern and eastern portions of the north Atlantic. In order that all official hydrographic data from the north Atlantic should appear in one series—the Hydrographic Bulletin of the latter Council—it has been requested that the countries adhering to the North American Council should forward their data for publication in that bulletin.

UNITED STATES

The fishery investigations of the United States Bureau of Fisheries are carried on by a staff of 43 biologists in its Division of Scientific Inquiry, the chief of which is Elmer Higgins. Within the division are section heads in charge of scientific work in the several natural geographical divisions of the country. Those along the northern border of the United States are: Frederick A. Davidson, in charge

Pacific fisheries investigations; John Van Oosten, in charge Great Lakes investigations; and Oscar E. Sette, in charge North Atlantic investigations, also director of the United States Fisheries Biological Station, Woods Hole, Mass. Studies on particular fisheries in the North Atlantic section are in the hands of particular research workers as follows: Wm. C. Herrington, haddock; Oscar E. Sette, mackerel; Wm. C. Schroeder, cod. The last-named resigned in June, 1932, to join the staff of the Woods Hole Oceanographic Institution but has kindly continued his studies of the cod, though on a reduced scale. Attached to the North Atlantic staff as assistants are John R. Webster, Wm. C. Neville and F. E. Firth.

In addition to the permanent staff, facilities for marine investigations were provided volunteer investigators at the United States Fisheries Biological Station at Woods Hole, Mass., in 1931, but in 1932 and 1933 the necessity for economy caused a discontinuation of this custom.

Until 1932 the Bureau of Fisheries operated a research ship, U. S. F. S. *Albatross II,* in the offshore waters of the North Atlantic, the U. S. F. S. *Pelican* along the coast of Maine, and the U. S. F. S. *Phalarope* in the vicinity of Woods Hole, Mass. Since 1932, *Albatross II* was decommissioned, *Pelican* was laid up, and *Phalarope* was replaced by a 40-foot motor launch, *Phalarope II.*

Fishery statistics are collected by the Division of Fishery Industries and published as separate bulletins and in the annual report of the Division of Fishery Industries and also in synoptic form in the annual report of the United States Commissioner of Fisheries. The statistics are collected by statistical field agents employed solely for that purpose and by local agents in Boston and Gloucester, Mass., Portland, Me., and Seattle, Wash.

On the Atlantic coast research in physical and biological phases of oceanography, related to fisheries biology, is also carried on by the Woods Hole Oceanographic Institution, the director of which is Henry B. Bigelow. The institution has a permanent staff of thirteen members; grants about fourteen fellowships annually; and provides facilities for approximately fourteen independent investigators at its laboratory. It operates the research ship *Atlantis,* and a 40-foot motor-boat, *Asterias.*

MACKEREL INVESTIGATIONS

The mackerel investigations begun by O. E. Sette in 1925 continued under his direction during the last three years. Observations on relative importance of year classes, their variations in geographical and seasonal distribution, their rates of decline in abundance, and the effects of these on the success of the commercial fishery have provided a basis for reasonably reliable annual predictions of the abundance of mackerel. The forecasts appeared in *U.S. Bureau of Fisheries, Fishery Circulars, 4, 10, and 14,* for 1931, 1932 and 1933, respectively. Latterly, these have been used by the mackerel fishing industry in planning exploitations of the fishery under provisions of the National Industrial Recovery Act.

Of particular interest in the field of marine fishery research have been the following conclusions and indications proceeding from the three years' work:

1. The numbers of mackerel surviving to commercial size differ greatly as between year classes. In descending order of numerical richness the year classes are provisionally ranked as follows: 1923, 1930, 1931, 1928, 1921, 1929, 1927, 1924, 1922, 1925 and 1926.

2. There appear to be two types of year class, a "persistent type" (1923, 1930, 1931) and a "transitory type" (1921, 1927, 1928). The persistent type has a low rate of decline, persisting strongly in the population for six years or more, while the transitory type declines at a high rate and three years after reaching commercial size remains in only negligible quantities in the United States fishery. The persistent type has not been demonstrated to occur in abundance in waters off the Canadian coast while the transitory type has composed the entire population in Canadian waters, if the relatively few samples available may be regarded as representative. The growth rate of individuals of the persistent year classes, so far as has been examined, appears to be considerably lower than that of the transitory. The differences between types of year classes are discussed in detail in the above-mentioned *Fishery Circular No. 14*.

The results of the United States investigator, who finds that the abundance is caused by the inequalities in the numerical richness of the year classes, contrast sharply with those of European investigators who found that abundance of mackerel was governed by meteorological and hydrographical conditions of the current year. This is probably due to the differences in sampling methods. Reflecting the relative importance of the various branches of the fishery, the United States samples were drawn mainly from the purse-seine fishery throughout spring, summer, and fall, while the Europeans have drawn samples mainly from drift-net and pound-net fisheries of the spring and autumn seasons, the purse-seine fishery being of negligible importance in European waters. Such studies as have been made on the abundance in drift gill-net fisheries of the United States indicate that the apparent changes in abundance are caused by current hydrographic conditions, just as in European waters.

The investigations of conditions of the spawning grounds intended to throw light on the causes of inequality of year classes were terminated in 1932 when the necessity of economy removed from service the research vessel *Albatross II* with which this work had been carried forward to the stage where plankton towing technique had been developed to a point which appeared satisfactorily quantitative for this particular purpose. Curtailment of personnel and expense funds, which occurred at the same time, has caused delay in the study of materials resulting from the cruises that took place previous to cessation of field work. Preliminary examination of the relative abundance of eggs and larvae in the plankton of the various years are such as to cause one to suspect that the theory that poor year classes are due to excessive mortality in the early larval stages may not be valid for the mackerel.

During the spawning seasons of 1931 and 1932, at Woods Hole, Mass., Leonard G. Worley investigated the rate of incubation of mackerel eggs at different temperatures. His results appeared under the title of "*Development of the eggs of the mackerel at different constant temperatures*," in *The Journal of General Physiology. Vol. 16, No. 5, pp. 841-857, May 20, 1933.* He found that the incubation period was 2 days at 21°C. and 8½ days at 10°C. with rates at intermediate points which may be defined by the temperature characteristics: μ=24,900 below 15°C. and μ=19,000 above 15°C. Mortality was least at 16°C. but typical development took place at all temperatures between 11° and 21°C.

This is in contrast with the results of C. M. McCallum, as reported in the last Proceedings, who found a temperature of 15°C. necessary for the proper development of mackerel eggs at Shippegan, N.B.

HADDOCK INVESTIGATIONS

The program of investigation outlined in the last Proceedings has been followed during the past three years under the direction of Wm. C. Herrington, assisted by John R. Webster. In it the statistical and biological analysis of changes in the haddock population on the New England and Nova Scotian banks had prominent place and has provided some of the most important results. Lack of adequate records from earlier years prevented a detailed study of fluctuation prior to 1923. Since that year, wide fluctuations occurred, the catch rising from 80 to 235 million pounds in 1929, and declining to 132 million pounds in 1933. But gross figures on the catch are of little value in depicting the changes in abundance. During this period there was a great expansion of the fleet in response to wider markets reached by the product as a result of improved processing methods and later there were the depressing effects of the economic crisis.

The fluctuations in the abundance of haddock, as distinguished from fluctuations in landings, have been determined by means of the "catch per trawler day" computed from detailed catch records of a group of large otter trawlers. On Georges bank and South channel, which have supplied eighty per cent of the haddock catch during the past ten years, the catch per day increased from 13,000 pounds in 1923 to 29,000 in 1927, declined to 7,500 pounds in 1930, and again increased to about 10,000 pounds in 1932 and 1933. However, the relative abundance during the last two years was substantially less than indicated by the 10,000-pound datum, for increased use of more efficient trawls at this time may have increased the catch per day appreciably.

Biostatistical evidence indicates that the high level of abundance reached during 1926-1928 was the result of two or more exceptionally successful year classes spawned during the period 1921-1924. The rapid decline during 1928-1930 resulted from an intense fishing at a time when there were few recruitments of young fish from the very poor spawning years from 1925-1928. The partial recovery during the last two years resulted from a fairly good year class spawned in 1929.

The data for the Nova Scotian banks, including Browns, La Have, Western, and Banquereau, are scanty up until recent years for the United States fleet did little fishing in this area until 1930. However, such evidence as is available indicates that the same year classes which have predominated in the Georges Bank region have also been the major elements in the population on the Nova Scotian banks. Due to the much slower growth rate in the latter region, the young fish did not affect the commercial catch until nearly two years later than on Georges bank.

The composition of the population indicates that from 1931-1933 there has been little or no movement of young haddock between the two general regions considered above which are separated by the relatively deep water of

the Fundian channel. However, in some years there appears to be a considerable movement across this channel of fish of four years and older. The studies of this question have not yet been sufficiently detailed to determine whether this is a fairly regular occurrence.

Attempts have been made to trace migrations by tagging, but although experiments on the Maine coast have yielded returns of about six per cent in the first year, only one return has been obtained from fish marked on the offshore banks. This work was done from dories of commercial line trawlers and under considerable difficulties. On a research or chartered vessel the technique probably could be sufficiently improved to produce a much better survival of marked fish and therefore increased returns. Limitation of personnel has prevented further pursuit of this method.

Studies by Lionel A. Walford of the abundance and distribution of the eggs and larvae of haddock coupled with the drift bottle experiments of the Bureau of Fisheries indicate that during 1931, 1932, and 1933 spawning on Georges bank usually is heaviest in March on its northern and eastern portions; sometimes also in South channel. There appears to have been little or no exchange of larvae between Georges bank and the Nova Scotian banks. In the area surveyed, large larvae have been found in greatest numbers in the shoal region of central Georges and young fish appeared in greatest numbers on southeastern Georges, apparently spreading from there to the northern edge of Georges bank and then to South channel. Annual differences in the degree to which the current was found to set off the southern edge of Georges bank may contribute to the explanation of some of the poor year classes in this region.

Although it is not yet known whether the fishery is causing depletion, it is desirable to seek the elimination of wasteful and destructive practices wherever this can be done without serious inconvenience or increased costs. Unnecessary destruction of unmarketable fish is so obviously wasteful that considerable effort has been devoted toward its elimination.

The otter trawls in use by commercial fishing boats at times capture great numbers of haddock below commercial size, which are thrown overboard as trash and constitute a complete economic and biological loss. The extent of the waste may vary from a small percentage of the total catch to as much as seventy-five per cent or more of the total. During 1931 and 1932, experiments with various types of gear designed to reduce the capture of undersized fish showed that of the various devices tested here and in Europe, the most effective type practical for our fishery was the use of large size diamond mesh in the cod-end and upper parts of the trawl. A cod-end mesh of $4\frac{3}{4}$-inch, stretched diameter, new netting, would reduce the catch of fish below market size of $1\frac{1}{2}$ pounds to about one-fifth of the number taken by the usual commercial net and permit the escape of a very few fish of the smallest scrod size. In addition, the catch of small trash would be greatly reduced. Several trawls of this type were fished commercially from the trawler *Kingfisher* with excellent results. A manuscript containing the results of this work has been submitted for publication in the Investigational Report series of the Bureau of Fisheries.

COD

Cod investigations from 1931 to 1933 took place chiefly in the region of Mt. Desert where 1,199 fish were tagged in 1931 and 1,481 in 1932. A few (172) were tagged on Nantucket shoals in August, 1931, and 644 at Woods Hole in January, 1931 and 1932. As about 41,500 cod had been tagged from 1923 to 1930 the total to the end of 1933 was increased to about 45,000 for the region between southern Nova Scotia and Delaware. A report dealing with the cod inhabiting the Nantucket Shoals region was published in 1930.

Off Mt. Desert the results of cod tagging experiments of 1931 to 1933 have agreed in general with those obtained heretofore in this locality in that: (1) from twenty to thirty per cent of the fish are reported recaptured on or adjacent to the tagging grounds within eighteen months, proving that a large proportion of the stock present at a given time remains localized for at least one or two years; (2) a noticeable scattering of fish takes place northeastward to the bay of Fundy-Nova Scotia region and a few stragglers go southward toward cape Ann.

In the experiments prior to 1930, metal strap tags were used exclusively and very few returns were reported later than eighteen to twenty months after tagging, due to the tags dropping from the fish. In the fall of 1930, and in 1931, most of the fish were marked with celluloid disc tags (attached to the caudal peduncle) while in 1932 another type of mark, the celluloid belly tag was used exclusively. The percentage of returns from cod marked with the new style tags has been well-maintained for two or more years indicating a much higher degree of permanence than was the case with the old-style strap tags.

FISHERY STATISTICS

The publication of fishery statistics of the United States now conforms to the first seven principles adopted by the North American Council at its 18th meeting (see p. 7) with the exception of Nos. 2 and 4. No 2, recommending separate listing of species, has been followed in the case of all species except those of the family *Pleuronectidae*. In this family, the halibut is reported separately but all others are grouped under the heading: Flounders. Separation of the various species of flounders has proven impracticable thus far, inasmuch as they are often marketed in mixed lots. No. 4, recommending publication according to statistical regions demarcated on the chart approved by the council, has been followed, except for the product of certain fisheries where the origin of the catch is in a region other than the one in which the fishermen reside. It is anticipated that this will be satisfactorily adjusted in the near future.

The eighth recommendation is being followed with respect to the two species, haddock and mackerel, to which the United States is devoting special biological studies.

2456—3½

HYDROLOGICAL INVESTIGATIONS

During the period 1931 to 1933 the Bureau of Fisheries collected serial temperature and salinity data and made plankton tows at numerous stations in the gulf of Maine and adjacent waters in connection with surveys on haddock spawning and in the oceanic bight between cape Cod and cape Hatteras in connection with surveys on mackerel spawning as summarized below:

Year	Stations occupied during surveys on haddock spawning	Stations occupied during surveys on mackerel spawning
1931	179	151
1932	51	239
1933	51	

With the decommissioning of the *Albatross II* in the spring of 1932 the mackerel survey work terminated, though continuation of the haddock surveys on a curtailed scale has been provided by the kindness of the Woods Hole Oceanographic Institution in making available the *Atlantis* for this purpose.

Certain of the results of the work in the gulf of Maine are touched upon in the section on haddock investigations, but a complete technical treatment of the data has not yet been possible. On the other hand, the hydrographic data resulting from observations between cape Cod and cape Hatteras have formed a basis for Bigelow's "*Studies of the waters on the continental shelf, Cape Cod to Chesapeake Bay.*" *I The cycle of temperature. Papers in physical oceanography and meteorology published by Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, Vol. II, No. 4. Cambridge, Mass., December, 1933.* Papers on the salinity and circulation of this region are anticipated. The plankton collections are being studied by Mary Sears.

The Bureau of Fisheries has continued to receive daily surface sea-water temperatures from between forty and fifty lightships and lighthouses along the Atlantic coast. The results of a study of these has appeared in: "*A Geographic-Ecological Analysis of the Seasonal Changes in Temperature Conditions in Shallow Water along the Atlantic Coast of the United States,*" *by A. E. Parr, Bulletin Bingham Oceanographic Collection, Vol. IV, Art. 3, January, 1933, New Haven, Conn.*

The main hydrological investigations of the Woods Hole Oceanographic Institution during the years 1931-33 can be summarized as follows:—

1931.—Mid-Atlantic Section, latitudes 52° 31′ N. to 36° 40′ N., July.
Survey of the Continental Shelf, Cape Cod to Cape Hatteras, October.
Nova Scotia to Bermuda, December.

1932.—Chesapeake Bay to Bermuda, February.
Mid-Atlantic Section, from latitude 35° N. to the Equator, March.
Haiti to Bermuda, April.
Bermuda to Chesapeake Bay, April.
Survey of the Continental Shelf, Cape Cod to Chesapeake Bay, June.
Nova Scotia to Bermuda to Chesapeake Bay, September.
Chesapeake Bay to Bermuda, December.

1933.—Bermuda to Elbo Bay, February.
Survey of the Caribbean, March and April.
Four coastal sections, Florida to Hatteras, May.
Five surveys of the Gulf of Maine, July to December.

During this period the *Atlantis* cruised approximately 42,800 miles and occupied 906 stations. Besides the routine observations for temperature, salinity, and oxygen, at many stations a complete series of samples was also analyzed for phosphates, nitrates, nitrites, and alkalinity. The corrected observations are being published annually in the *Bulletin Hydrographique of the Conseil Permanent International pour l'Exploration de la Mer.*

The more specialized investigations included observations for the penetration of light at typical oceanic and coastal localities, evaporation determinations, pilot balloon work, collection of bottom samples from both coastal and deep waters, and sonic soundings from the relatively unsurveyed areas in the western Atlantic and Caribbean.

Fifteen shorter papers dealing with various physical investigations have thus far been published. (*Woods Hole Oceanographic Institution, Collected Reprints, 1933).* By the end of 1933, four longer physical oceanographic studies had also appeared in *Papers in physical oceanographic and meteorology published by Massachusetts Institute of Technology and Woods Hole Oceanographic Institution.*

The hydrographic observations of the United States Coast Guard during the Ice Patrol seasons 1931-33 can be summarized as follows:—

1931.—March 18-June 19.—18 stations from the critical southern area of the "tail" of the Grand Banks.
June 19-29.—54 stations from northern, eastern, and southern slopes.
July 4-Aug. 10.—122 stations on an extended northern cruise.
1932.—April-June.—3 surveys (35-40 stations each) of the critical area.
1933.—May 8-June 4.—25 stations between Flemish Cap and the eastern slope of the Banks.
June 26-July 24.—112 stations on a repetition of the 1931 northern cruise.

In addition to serial observations for temperature and salinity, frequent surface temperature charts were prepared to supplement and aid in the interpretation of the dynamic topographic maps of the area off the southern tip of the Grand banks, so critical in determining the drift of icebergs.

The two extended northern cruises fully surveyed the area between Labrador and Greenland. In the course of this work opportunity was not lost to secure more than 2,500 important sonic soundings.

Besides the report of these investigations published each year in the *U.S. Coast Guard Bulletins*, an exhaustive study of the ice conditions in the northwestern North Atlantic has recently appeared (*Edward H. Smith, Arctic Ice, with Especial Reference to its Distribution to the North Atlantic Ocean, Scientific Results Part 3, The Marion Expedition, U.S. Coast Guard Bulletin No. 19, 1931).* A comprehensive paper on the hydrography of the same area is now in preparation.

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Reports on the activities of the Woods Hole Oceanographic Institution have been regularly presented to the council at its meetings.

1. *Hydrography.*—The institution commenced active work at sea with its new research ship *Atlantis* in the summer of 1931, when a profile was run across the Atlantic along latitude 56° N. to longitude 30° W., thence south to the Azores and westward. It was planned to continue this to the Nova Scotia coast but the last few stations were abandoned because of stress of weather.

At the meeting in October, 1932, the chairman reported that the institution had accomplished four quarterly cruises of the Cape Sable-Bermuda-Chesapeake Bay triangle, as well as an extensive cruise in February to South America along longitude 35°, and two summer cruises in the gulf of Maine.

In 1933 the primary objective of *Atlantis* cruises was temporarily shifted from the study of seasonal variations of the water between Bermuda and the American coast to an intensive chemical and physiological investigation of the gulf of Maine, where two cruises totalling 140 stations had been completed. As a joint undertaking with the Bingham Oceanographic Foundation during the winter of 1933, a network of 124 stations was occupied in the Caribbean sea.

Up to December, 1933, the *Atlantis* had occupied 898 stations, the total number of temperature and salinity observations being 9,280; oxygen determinations 7,185; alkalinity measurements 3,882; phosphate determinations 4,591; nitrate and nitrite determinations 1,756; evaporation measurements 250 and deep sonic soundings 741.

2. *Drift Bottles*

Through cooperation of the Woods Hole Oceanographic Institution, drift bottle investigations were continued in 1933 in connection with the haddock work from Nantucket Shoals to Nova Scotia.

3. *Plankton*

In the summer of 1931 collections to determine the vertical distribution of zooplankton were made at ten stations during *Atlantis'* crossing of the Atlantic, with horizontal closing nets, while tows, especially for eel larvæ, were carried out at a number of stations. In 1932, the plankton program included hauls in connection with the study of food supplies for planktonic animals and study of the distribution of copepods; closing net hauls to determine the vertical migration of copepods in connection with light intensity measurements; intensive quantitative survey of phytoplankton in the gulf of Maine; and deep tows offshore. In 1933, investigation was commenced of the bathypelagic distribution of animal plankton in the offing of Woods Hole, using horizontal closing nets at close intervals down to 3,000 metres; the study of vertical distribution was continued; experiments with a triangular otter trawl were made on the southern cruise of *Atlantis;* and a periodic program of vertical tows was inaugurated in the gulf of Maine.

4. *Mackerel*

To provide for the continuation of the United States Bureau of Fisheries investigation of the biology of the mackerel, *Atlantis* was sent out on two cruises for this work during June and July, 1932.

5. *Haddock*

In June, 1933, *Atlantis* was assigned to an investigation of eggs and young of the haddock for the United States Bureau of Fisheries.

CANADA

Under the Minister of Fisheries the Biological Board of Canada conducts scientific investigations of varied nature in relation to the fisheries. During the period under review this was under the chairmanship of Professor J. Playfair

McMurrich. Investigations of the various sea fisheries of the Atlantic coast are carried out by members of the staff of the Atlantic Biological Station, and by volunteers from the universities. During the period the staff related to work reviewed by the council has consisted of A. G. Huntsman, director; H. B. Hachey, hydrographer; R. A. McKenzie, cod investigator; and V. D. Vladykov, haddock investigator.

The Department of Fisheries through its staff of local officers is responsible for the collection of statistics, as well as the provision of varied information related to the fisheries.

COD INVESTIGATIONS

In 1932 the investigation of the cod was resumed by Canada in the assignment of R. A. McKenzie to this work. Initially collections made by the International Passamaquoddy Fisheries Commission near the mouth of the bay of Fundy were explored to determine the progress of the spawning of the cod in that region, which was found to be principally from the middle of March to the end of April.

Study of the fishery on the outer coast of Nova Scotia, east and west of Halifax, shows a limitation in season to late spring, summer and autumn, the height being in mid-summer. Hand lines are mostly used rather than "line trawls," this apparently owing to the spotty nature of suitable bottom. The central part of the area (Sambro peninsula) shows a drop in the catch in the middle of the season (July to September), which occurs only slightly to the eastward and to the westward. This drop is not only in the volume of the catch for each month, but in the volume of the catch per unit of fishing gear, which indicates definitely a reduced stock during that period. The reduction affected the fish in all of the three layers of the water,—warm upper, cold intermediate, and warm lower layers. The facts indicate a varied population and rather complicated migrations, partly on and off shore and partly coastwise. Some of the fish are relatively stationary and others migrate rather extensively.

There are definite changes in the abundance and in the character of the cod, going from the upper to the lower of the three layers of water, there being an increase in the abundance of the fish and also in the average numbers of the gill rakers and of the vertebræ in each fish. There is some evidence of slight movement inshore from layer to layer, but none of movement in the reverse direction. There was apparently an inshore movement at the close of the slack period in the fishing, when the shallow water began to cool.

There is spawning of some of the cod in the inlets (Halifax harbour to St. Margaret bay) in the autumn, beginning even before the end of September and reaching a maximum in November.

A thorough study of the results of the tagging of cod on the outer Nova Scotia coast during the years 1925, 1926 and 1927 (*Proc. N. Am. Coun., No. 1, p. 22*) has revealed varied movements. Restricted migration (within a limit of 25 miles, or 40 kilometres) is found only westward of Canso and not at Cape Breton. This movement is offshore to deeper water in the autumn and early winter and to shallower water, usually shoreward, in the spring and early

summer, corresponding with the seasonal changes in the temperature of the water. Orderly extended migration was to the offshore banks (Banquereau) at the eastern end (Cape Breton) of the region in the autumn and early winter, but at the western end the corresponding movement was coastwise south westward from Shelburne to Seal island in rather deep water during the winter. This difference is related to the very cold water during winter along the coast at the eastern end.

A varying proportion of the fish are classed as rovers, since their movements are seemingly at random and in nearly all directions. From both Seal island and Shelburne they moved principally northeastward along the coast, and progressively from year to year at the rate of about 200 kilometres a year. At Shelburne high temperatures about August or September are considered responsible for a secondary offshore movement from the harbours and near the headlands to somewhat deeper water, which may be followed by a return to shallow water as the temperature drops.

From the middle of May to the middle of September, 1933, the cod in the vicinity of Halifax showed rather uniform feeding conditions, but differing in the three layers. Going from the warm upper layer (inshore) through the cold intermediate layer to the warm deep layer (offshore) there was an increasing percentage of fish with empty stomachs and the food changed from one predominantly of brittle stars, molluscs and amphipods to an increasing percentage of crabs, shrimps, and fish, the latter reaching thirty per cent. Food became less and less frequent in the inshore cod from the middle of September to the middle of November, corresponding with the onset of spawning.

Observations on cod held in tanks show that they tolerate temperatures up to 20° C. Twice as much growth occurred during the warm period (July to August) as during the cold period (March to April). The smaller fish (30 to 40 cm. long) continued to eat with as low a temperature as 1·5° C., but the larger fish (60 to 70 cm.) ceased at a slightly higher temperature; on the other hand the optimum feeding temperature was lower in the larger fish than in the smaller, that for the latter being between 12 and 18° C. More feed was taken at higher temperatures, but a sudden drop in temperature during the summer resulted in more feed being taken and a sudden rise had the reverse effect.

In respect to coloration it has been found that cod can change not only their colour and shading very rapidly (minutes) but also the pattern.

HADDOCK INVESTIGATIONS

R. A. McKenzie investigated the haddock of the bay of Fundy in 1931. At the mouth there are, generally speaking, spring and autumn fishing seasons, more pronounced on the New Brunswick side, and becoming less and less distinct going into the bay, changing to a short summer season. This seems correlated with water temperature. In the Passamaquoddy region during the period 1925 to 1930, inclusive, very few, if any, haddock were taken when the temperature of the water dropped below 2·2°C., irrespective of the time this occurred, or of the duration of the cold period. The catches tended to decrease when the temperature rose above 8°, and at the high temperatures there was a tendency toward irregular high catches, failure in the catch not meaning the absence of fish, which were found with the drag trawl to be present and eating, though not taking the baited hooks.

In 1932 V. D. Vladykov was assigned to investigate the haddock on the outer coast of Nova Scotia. Haddock of from three to four pounds in average weight are found to spawn at the entrance to St. Margaret bay in April and May, and the spent fish move eastward. Haddock of from five to seven pounds weight are taken inshore from June to August, when the haddock (of similar size) are least abundant on the offshore banks, which indicates that there is a common migratory stock.

The inshore spring (March to May) fishery is confined to the region west of the Sambro peninsula. Around that peninsula the bottom is unsuitable, and east of it the fishermen for economic reasons operate their gear so as to catch cod rather than haddock. At this time the latter approach the shore to spawn. Records of bottom temperatures and catches show that practically no haddock are taken until the temperature rises above 34°F.

During the summer of 1932, there were large numbers of small haddock (20 to 40 cm. long) along shore in the Halifax area. These were found to be from two to four years old. The number of these captured definitely dropped when the bottom temperature rose above 11°C., and it is believed that they moved out at this time. However, in tanks they seemed quite tolerant of temperatures as high as 20°C. They took a variety of food by both sight and scent. In the sea bivalve mollusks and *Polychaete* worms were their principal food, small crustaceans coming next, this in contrast to the large haddock, which were found to be taking brittle stars, sea urchins, and herring eggs.

A study of possible racial characters shows that going from South channel (near cape Cod) to Halifax the average number of both vertebrae and gill-rakers rather steadily increases.

SALMON INVESTIGATIONS

The salmon of the rivers emptying into the bay of Fundy appear never to move seaward from the bay to any particular extent. The largest fishery in the bay is for those related to the Saint John river, which are taken by drift-nets along the course of the water from that river, from the harbour at the river mouth seaward toward the island of Grand Manan at the mouth of the bay. The season extends from late May to the middle of August, after which time fishing is prohibited, although salmon continue to appear until as late as December at least. In 1932 experimental fishing in Saint John harbour during November and December showed the run at that time to consist of very immature fish (mostly females) intermediate in growth between grilse and the ordinary salmon and averaging about nine pounds in weight. Grilse run in limited numbers during the summer, starting in June. In late summer salmon of about a pound in weight, that is intermediate between smolt and grilse, are not infrequently taken in the herring weirs along the coast from Saint John to the Quoddy region, sometimes in rather large numbers, but they are not taken in the rivers or river estuaries. Tagged kelts, liberated in the salt water of Saint John harbour, have been recaptured, according to the records of the Department of Fisheries, only in the fishing area and in the river itself or its branches, showing no straying to other river systems.

The salmon of the rivers at the head of the bay of Fundy nearly all return to spawn as grilse. However, a considerable portion of those of the Minas system, apparently as a result of going out into the bay of Fundy and being unable to find their way back through Minas channel, provide a fishery on the south side of the channel and the neighbouring part of the coast of the bay, where they are taken in weirs. These range from a pound to over thirty pounds in weight and are nearly all virgin fish that have been from less than to over four years in the sea without spawning.

The Annapolis salmon seem similarly to consist of inside fish which do not leave the basin, and outside fish unable to find their way back and taken principally in nets at Gulliver cove some miles west of Digby gut. Tagged kelts liberated in a branch of the Annapolis river show, according to the records of the Department of Fisheries, that a large proportion are lost to the river, straying to Newfoundland.

HERRING INVESTIGATIONS

A study of the fishery for immature herring that is carried on with weirs in the bay of Fundy from Saint John to Grand Manan shows that the catches are definitely related to the temperature of the water for individual years from 1926 to 1930, being largest with the highest temperatures. This is apparently the result of greater activity with higher temperature causing more fish to reach the weirs. The principal feeding season, centred in July, gives lowered catches, presumably since the fish, while feeding, remain relatively stationary in the water.

The herring are carried in the surface movement set up by the wind, west winds carrying them to, and east winds from, the east shore of a bay. This shows that they are to be considered as comparable with surface plankton. The principal variations in their local distribution are seen to be the result of movements of the superficial water, set up by mixing of light estuarial water, resulting from heavy discharge from rivers, with the deeper, heavier water. With very heavy discharge, as in spring freshets, the herring are carried from estuaries, such as those of the Digdeguash and Magaguadavic rivers of Inner Passamaquoddy bay, into the middle of the bay, and from that point to the chief mixing points where the light water is consumed. Weirs located near these points usually do best, therefore, in the spring, and are known as "spring" weirs. With decreasing discharge from the rivers, the fish are carried progressively nearer to the estuary, as the course of the light water is shortened, going to the nearer mixing points. Weirs so located usually fish best with a quick run-off, as when the rivers are low in late summer and autumn. They are hence known as "fall" weirs. With a very heavy downpour at such a time, the fish are at first carried from the estuaries, if present there; then taken in a week's time to the "spring" weirs; and finally in two weeks' time brought back in quantity to the "fall" weirs at the estuaries.

Those handling herring report local differences in fatness and such have been found by N. A. McNairn, as the result of the measurement and weighing of fish of various sizes taken at various localities from the Quoddy passages inland to Oak bay, off the St. Croix estuary. A correlation was found between

the degree of fatness and the prevalence of food in the stomachs, as examined by W. H. Johnson. There was likewise correlation with the abundance of suitable food in the plankton, as determined by Anne M. Jeffers. Also study of the vertical distribution of the plankton by G. W. Jeffers showed that where the herring were fattest the food organisms were steadily available at the surface throughout the day, whereas in the other localities they came to the surface only at night. Helen I. Battle found experimentally that the herring would not feed in darkness, which serves to explain the observations of the weir fishermen, in localities where the food is largely absent from the surface during the day, that the fish have most feed in them when there are moonlight nights.

A mechanism is demonstrated that provides the herring with an abundant supply of food. With heavy river discharge, the fish are carried at the surface to the chief mixing points. The mixing continues to bring deeper water to the surface and with it the food organisms, thus permitting continuous feeding so long as there is sufficient light. Further, it has been found that the movement of deep water to a deep mixing place, as a result of the hydrodynamic forces, carries the food organisms to that place and concentrates them where the herring also are concentrated as a result of surface movement.

FISHERY STATISTICS

Statistics of the fisheries of Canada's Atlantic provinces have been collected regularly almost from the time the country was constituted by Confederation in 1867. From time to time improvements have been made in the methods employed in the collection of these statistics and efforts are now being steadily put forth to have this conform to the principles laid down in the report of the Committee on Statistics, which was adopted by the council in 1931 at its 18th meeting (see p. ..). The first seven principles have been followed except in the cases to be mentioned. It has as yet not been practicable to fully carry out No. 2, as hake and cusk are listed together, also clams and quahaugs. Moreover, several species of small flatfish have not been separated out, but are partly listed as "flounders" and partly as "soles." In the case of No. 3, all catches are given on a fresh basis, and the conversion factors used in bringing all data to this basis are specified. However, for cod, haddock, hake, cusk, pollock and halibut the fresh basis is not the fish when whole, but with the entrails removed, and for swordfish and albacore (now listed under the entry "tuna" in Canadian statistics), with head, tail and entrails removed. The factors necessary for conversion of these figures to the weight before dressing have not yet been secured. It has not yet been possible to relate the catches of the various fish to the gear, fishing craft and fishermen, by which they are made, which is the substance of principle No. 5.

BAIT INVESTIGATIONS

Experiments were performed in 1931 to determine the value of bait preserved with salt or formaldehyde in comparison with the same kind of bait in the fresh state (frozen or unfrozen). In certain cases bait preserved in formaldehyde gave the best catches, particularly with hake (*Urophycis*), perhaps

as a result of remaining longer on the hooks. In other cases salt bait was the best, as for certain flatfish, which were taken on no other kind. There are many variable factors which require further analysis.

WATER TEMPERATURE

Analysis of surface temperatures taken daily at a series of coastal stations from the bay of Fundy to the gulf of St. Lawrence shows the monthly mean to be highest for the month of August at all points, though the highest point may not be till the early part of September in the region of the bay of Fundy. At all points the waters are coldest in February. Very stable conditions are to be found in the bay of Fundy region, the daily temperatures giving a fairly smooth sine curve, and the range in temperature being least throughout the year, as shown by the region having the lowest mean for August and the highest mean for February. The outer coast of Nova Scotia and the north shore of the gulf of St. Lawrence show some very abrupt changes in the temperature of the surface water.

The trend of temperature during the five years since the records were begun in 1929 has been at first upward and then downward, a warm peak having been reached in 1930 or 1931. This is most striking for the north shore of the gulf of St. Lawrence (cape St. Mary), the August mean dropping from 13·8° C. in 1931 to 11·9° in 1932 and 6·9° in 1933. This is indicated as being the result of a large scale movement of Labrador current water through the strait of Belle Isle.

HYDROLOGICAL INVESTIGATIONS

During the summer seasons of 1932 and 1933 a study was made of the shore waters of the Halifax area on the outer coast of Nova Scotia. The surface water to a depth of 30 metres, offshore, and of 60 metres, inshore, was above 5°C. in temperature and below 32°/₀₀ in salinity. The deep water below 70 metres and offshore only was also above 5°C. and in salinity above 33·5°/₀₀. The intermediate water was of intermediate salinity (32 to 33·5°/₀₀) but very cold (below 5°C.). During the summer the upper layer thickened and became warmer in such a way as to indicate not only local warming but movement of warm water to the area. The intermediate layer changed greatly, the coldest water gradually disappearing in such a manner as to indicate considerable movement. As a result of the marked stratification, the character of the inshore water showed rather wide fluctuations from week to week, variations in bottom salinity of as much as 1·2°/₀₀ occurring within a week and in bottom temperature of as much as 9°C. in two weeks' time. These large variations occur chiefly in the spring and autumn, and result directly from wind action or indirectly from pressure gradients in the atmosphere. Bimonthly variations in bottom temperature of as much as 4°C. and in bottom salinity of as much as 0·5°/₀₀ are seemingly caused by internal tidal waves related to the phases of the moon.

Hydrodynamic treatment of the data for the summer of 1932 shows, on the whole, a southwesterly movement along the shore with maximum velocities in the area ranging from two miles per day in June to 17 miles per day in September-October. However, much variation was shown, the most unusual

being in September-October, when with a strong shoreward movement east of Sambro, there was a strong offshore movement west of it, the waters at the southwest of the area being subjected to a strong clockwise movement carrying a large body of water into the area close to the shore from the southwest.

In September of 1932 a southwest gale brought about very marked changes in the conditions. The offshore surface water was driven to the coast, piling up there and causing the cold intermediate layer to recede. The mixed water formed in the inshore area, being of greater density than the surface water offshore, moved away, when the storm subsided, at depths appropriate to its density, resulting in more or less of a return to conditions existing before the storm. This course of events produced locally great changes in temperature and salinity.

Experiments were conducted with a small laboratory tank to demonstrate the character of the currents resulting from the local mixing of superincumbent layers of water of very different density. As the density of the mixed water is intermediate between the densities of the superficial and deeper waters outside the mixing point, it was clearly seen to move outward at an intermediate depth while the superficial and deeper waters moved to the mixing point. If light water is introduced at a mixing point, the mixed water moves away superficially, while the outer water flows to the mixing point at a lower level. Wind blowing over the surface enhances the surface and subsurface movements, reducing the deeper ones.

The phosphate and oxygen content of the waters in the Halifax area during the summers of 1932 and 1933 were determined by J. M. Morton. In general they furnished corroborative evidence of the changes in the water shown by temperature and salinity observations, as in the case of the September storm of 1932. There was found to be a gradual diminution in the amount of phosphate in the surface waters from May to August, by the end of which month the surface values began to increase. The mixing due to heavy storms prevented further following of these changes. The water richest in phosphates was found near the bottom in Bedford basin, where oxygen was present to only 60 per cent of saturation as a result of the stagnant conditions. From the surface to a depth of 25 metres the water of the whole area is approximately saturated with oxygen at all times.

PLANKTON INVESTIGATIONS

The zooplankton of the Halifax area during the summers of 1932 and 1933 has been examined by Chas. E. Kearney. *Calanus finmarchicus* was the dominant species, making the plankton more abundant in the deeper water and particularly in the vicinity of Sambro bank. In both years the quantity of plankton was greatest in June with a decrease through July to August.

NEWFOUNDLAND

Following on a preliminary survey of the fishery situation in Newfoundand, and a report (1) thereon to the British Empire Marketing Board and the Newfoundland Government, these authorities entered into an agreement providing for a five year period of fishery research in Newfoundland. A sum of not more than $50,000 was made available for the outfitting of a suitable laboratory, and

a like sum annually for its service. These expenditures were shared equally by the two authorities above-mentioned. The research scheme recommended went into operation on April 1st, 1931, but was hampered and even threatened with withdrawal owing to the financial difficulties accompanying the world economic depression. The Empire Marketing Board was abolished as from October 1st, 1933, but its liability in respect to the Newfoundland Fishery Research Scheme was assumed by the British Dominions' Office. In February, 1934, representative government in Newfoundland was replaced by a Commission of Government, which took over the liability on the part of Newfoundland, and, through its Department of Natural Resources, the administration of the research laboratory.

The laboratory was established on a leasehold basis in the premises of Messrs. Harvey & Company at Bay Bulls, a fishing settlement eighteen miles south of St. John's. The premises were however purchased by the Government for a sum of $25,000 in June, 1934, with the double object of giving a greater degree of permanency to the laboratory, and of allowing greater scope for its activities.

The premises are equipped with the usual general laboratory equipment, and a sea-water circulation is available. In addition there are canning, smoke-house and cold storage installations. For deep-sea investigations a Mersey-type trawler —*ss. Cape Agulhas*—is owned and operated by the Government. This vessel is equipped for commercial trawling, bultow (long-line) fishing from dories, and for operating the usual hydrographic and plankton-collecting gears. Regular spring and autumn survey cruises over the entire Newfoundland fishing area are carried out. These cruises are normally of one month's duration, but in 1933 and 1934, for two and three months respectively in early spring, the vessel was used for commercial trawling under the auspices of the Government. This move has been made partly to provide employment, and partly to secure representative data on the varying positions of the main cod shoals, together with the associated hydrographic conditions. The ultimate objective of these and of the survey cruises is to establish a prediction service for the bank and the inshore fisheries. The frontage of the laboratory premises consists of wharves at which the trawler and other craft can berth and discharge. The inshore fishery and the hydrographic conditions attending it are studied by motor boat.

The scheme of research adopted by the original controlling authorities had the following scope and objectives:—

1. The accurate survey of the fishery resources, whether actively exploited or capable of exploitation.
2. The study of the life histories, the fluctuations in numbers (and the causes thereof), and the movements of the principal fishes with a view to
   (*a*) Predicting, if possible, the size and the points of incidence of runs of fish.
   (*b*) The amassing of statistics demonstrating maximum, minimum and normal densities of the stocks; these statistics to serve as a guide to the existing trade and to possible new enterprises, and as part-basis for future protective and other legislation.
3. The examination of existing methods of processing fish-products, the determination of any faults or disabilities therein, and the demonstration of improved methods where possible.

4. To devise means, where possible, of utilizing waste materials of the fishery.

The staff appointed to carry out this program consists, besides the director, of a bio-chemist, an assistant chemist, a physiologist, two biologists, and a technical assistant. In addition, two fishery assistants are employed, chiefly for field work, and other assistance is obtained as required.

The following account refers to the biological and hydrological investigations in the initial period (1931-1933). Investigations related to the technical side of the fisheries are reported on in the Annual Reports of the laboratory.

HYDROLOGICAL INVESTIGATIONS

The cruises of the research vessel have been so planned that, over a minimum period of five years, temperature, salinity and drift bottle data will be repeatedly obtained from a series of spaced-out stations in the Newfoundland fishing area. Hence a fair knowledge of the fluctuations in such a period of years will be secured. Attention has in the main been concentrated on gauging the variations in the relative degree of influx of masses of water of cold Arctic and warm Atlantic origin respectively. From the results of French investigations it would appear that the period of years immediately preceding 1931 was one during which warmer water influences were above normal, and that colder average conditions were to be expected to supervene. The results deriving from the Newfoundland observations appear to be in accord with this anticipation. In 1931, although the surface water layer had a temperature which was normal or just above normal, the warm layer had no great depth amplitude. The 4°C. isotherm did not drop below the 50-metre depth contour on the banks, and was in many parts to be found nearer the 25-metre level. In 1932 most of Grand bank was covered by water of a temperature between zero and 1°C. and there was an abundance of mixed (bank) water, since the Arctic current had apparently increased in intensity and flooded the area to an approximate depth of 50 metres. There was at the same time a strong influx of Atlantic water from the southwest, this influx occurring in the deeper water layers over the banks (where the fishery was good, as it was also in the S.E. coastal area sharing bank conditions) and towards the southwest coast, where conditions became too warm for a successful cod or squid fishery. The increased strength of the Arctic current was signalized by an increase in the development of plankton life and by the fact that drift bottles set free off the eastern coast of Labrador and Newfoundland were carried into the southern bays, and in at least eight instances into the Atlantic drift and hence across to points between the Azores, Norway and Iceland. In 1931 and 1933 (so far as existing returns show) this did not occur. In fact it appears that the increase in the degree of influx of Arctic water culminated early in 1933, when vast quantities of ice accompanied it down both the east and west coasts of Newfoundland. In the early summer of 1933 the water in most of the area was as a result colder and less saline than at the corresponding period in 1932. Plankton life also appeared to reach its point of greatest multiplication at or about the same time. In the fall of 1933 Atlantic influences were gaining to some extent, more saline water was found generally in surface waters of the area, and the amount of plankton suffered marked diminution, especially in respect to the numbers of species usually found only in Arctic water. (No resumption of intensified flow

of the Arctic current occurred in the winter and early spring of 1934; in spite of a very cold winter locally, practically no ice reached the southeastern area of Newfoundland, and the fishery was a week or two earlier than usual in commencing. This was in agreement with the course of hydrological changes at sea, but not with the expectations of the fishermen themselves, who anticipated much ice and a late season. The research vessel, during its operations throughout spring, found the water overlying the southern ledge of Grand bank to be warmer than at any time during the previous three years).

SURFACE DRIFT BOTTLES

The following returns were obtained from the liberation of surface drift bottles in the three years under review:—

	Liberated	Returned	Per cent Returns
1931	275	15	5·45
1932	385	58	15·06
1933	411	26	6·33

In the years during which an intensified influx of Arctic current does not occur there is apparently a smaller percentage return of drift bottles. From those liberated off the Labrador and east Newfoundland coasts practically no returns are then obtained, whereas in 1932, when the Arctic current increased to its maximum intensity for the period under consideration, there was a marked increase in the percentage number of bottles retaken. Not only were some half dozen bottles drifted across the Atlantic, but large numbers stranded in the southern bays. The latter has hitherto been considered to be a normal phenomenon, but these continuous investigations show clearly that this is not so.

PLANKTON INVESTIGATIONS

It was found that the volume of plankton forms, obtained by centrifuging the organisms retained in the standard Hjort silk net hauled from a depth of 100 metres to the surface, increased to a maximum with the increasing intensity of Arctic water inflow, and subsequently decreased in common with the decrease of that inflow.

	Average Volume in cubic centimetres per standard haul (microplankton)		Notes	
	Spring	Fall	Spring	Fall
1931	.....	3·0	.....	Scarcity. Warm water species prevail.
1932	7·3	7·8	Increase. Arctic species prevail.	Further increase. Arctic species prevail.
1933	24·1	7·8	Maximum reached. Arctic forms prevail.	Sharp decrease of Arctic forms. Increase of warm water forms.
1934	6·6	.....	.....	.....

Very common forms were enumerated and charted to demonstrate the variation in their numbers and distribution. It was however found that very few species are so closely restricted either to Arctic or warm Atlantic water as to be used with success as indicators of typical water conditions. Three animals in particular proved useful—*Sagitta serratodentata, Oikopleura vanhoffeni,* and *Oikopleura dioica.* The two latter, typical of cold and warm water respectively, varied both in degree and locality of occurrence.

The following average numbers were captured per haul in the whole area in the years 1931 (fall)—1934 (spring).

——	Oikopleura vanhoffeni	Oikopleura dioica
Spring 1932	635	0
" 1933	*1,342*	0
" 1934	327	0
Fall 1931	27	*526*
" 1932	*124*	214
" 1933	26	*416*

The transition is from a low number of the Arctic species (*O. vanhoffeni*) and a high number of the Atlantic-water species (*O. dioica*) at the outset, to the reverse state of affairs in the fall of 1932 and the spring of 1933; and to the subsequent tendency for the numbers of the Atlantic species again to gain at the expense of the Arctic species.

There is therefore a clear correlation between the variation in the physical condition at sea and the types, numbers and dispersal of certain typical species in the plankton. The movement of bait-fishes and of the marketable fishes themselves are also affected.

BAIT-FISHES AND SQUID

Caplin.—Investigations have shown that the caplin migration is one taking place directly in towards the coast, and not one in which dense masses of caplin strike the coast at certain points and then migrate coastwise. The upper limit of water-temperature tolerated by caplin has been established at 10½°C., but the optimum temperature for rolling (reproduction) is 7½°. Less than one per cent. of the spawning population is two years of age, the bulk being three years old. In caplin the scales do not develop before the first winter, hence there is normally no annulus in the scale to represent the first year of life. Small fry may however have a few scales showing an annulus. The movement of caplin to the heads of sea-inlets appears to be the expression of the anadromous tendency exemplified in increasing degrees in the related smelt and salmon. The pelagic occurrence of caplin larvae was studied in two successive years. The larvae were found to be most abundant east of the Avalon peninsula and off the east coast of the northern peninsula and Labrador.

Herring.—Little attention has been given to herring investigations. From a certain number of herring measurements and age determinations, however, it appears to be likely that the herring of Newfoundland resembled those of Norway in their movements. The chief spawning areas are probably in the south and

west, and there is evidence, from differing growth rates and size limits, that there are local races. As in the case of Norwegian herring the small fish of one, two, three and in some cases four years of age are distributed around the littoral waters; the medium-aged fish (four to seven or eight years old) are not located inshore in any numbers, evidently living an oceanic existence at this stage of life. Old and large herring are, however, commonly taken in the inshore nets.

Squid.—Two species of squid have been found in the Newfoundland area. The chief species is *Illex illecebrosus (Lesueur)*, which occurs only in the adolescent and adult stages, but does not spawn in the area. Very young forms of this species have not been located. On account of its very great importance as the preferred bait for the fall fishery an attempt has been made to find a basis upon which forecasts of its probable abundance could be made. Although the best temperature range for squid has been determined, and the probability of this range being attained on various portions of the coast can to some extent be predicted, attempts at forecasting runs of squid are handicapped by lack of observation of the survival index of the young broods. *Gonatus fabricii* (Licht) is the other squid species occurring. Only the very young forms are taken, and these especially in years when the Arctic current is of reduced volume. The adults of this species have not been found during these investigations.

SALMON INVESTIGATIONS

Considerable attention has been devoted to the biological analysis of the coastal and river runs of both Newfoundland and Labrador salmon. Approximately 5,000 salmon from various portions of the area have been measured and scale-sampled during each season.

The commercial fishery is based on the spring run, which consists of salmon striking inshore from the oceanic feeding grounds and about to enter the rivers to spawn. There is some evidence (varying growth-rate in sea, and number of years of parr life in the rivers, etc.) that different areas have more or less distinctive salmon stocks, although, particularly off the northeast coast, considerable mingling of these stocks occurs. The average salmon of the Newfoundland area is six years old, having spent four years of parr life in the river and two years on feeding migration at sea. There is considerable variation from this typical life history, however. As few as one, or as many as seven years of parr life can occur; the average is three years for the southern rivers, and gradually increases, in a northerly direction, to four and one-half off Labrador. The average growth rate achieved at sea, however, decreases from south to north. Spawning is accomplished at two yearly intervals in the north, but annually in the south, where also the largest proportional numbers of grilse occur. Owing to the high average number of parr years—the greatest yet recorded for the Atlantic salmon—a very large parr size can be attained.

Salmon due to stay three years at sea put on the best growth in the first year out; those due to stay two years show decreased first year growth, and those due to stay one year only put on the poorest growth. All over, the rate of growth at sea equals that of European salmon during the first year, but is considerably less during the second year.

Since the fresh-frozen salmon business is one involving costly outfits, there is a strong desire evinced by the trade to be put in possession of any prior infor-

mation available as to the prospects for the fishery each year. In 1932 and 1933 tentative forecasts, which were largely justified by the actual event, were issued as to the general prospects on the various portions of the coast. These forecasts were based on the study of the hydrological factors and on an analysis of the age-composition of the stock of salmon in previous years, particular attention being devoted to the relative numbers of grilse to all other classes.

COD INVESTIGATIONS

The outstanding importance of the codfish in the fisheries of Newfoundland renders it necessary that the major portion of the program of investigations should be devoted to the study of the general and the economic biology of that fish. There occurs annually on the coast of Newfoundland a unique inshore run of vast numbers of codfish, but the extent of the run is subject to wide fluctuations on different parts of the coast. These fluctuations are due chiefly to the varying temperature conditions from year to year. There is also a considerable fishery carried out by schooners on the banks, and as this is a fishery tending to dwindle as a result of the difficulty of earning profits, it is essential that any aid which science can offer should be forthcoming. The investigations have therefore been planned to include a complete biological survey of the stocks of cod over the whole area.

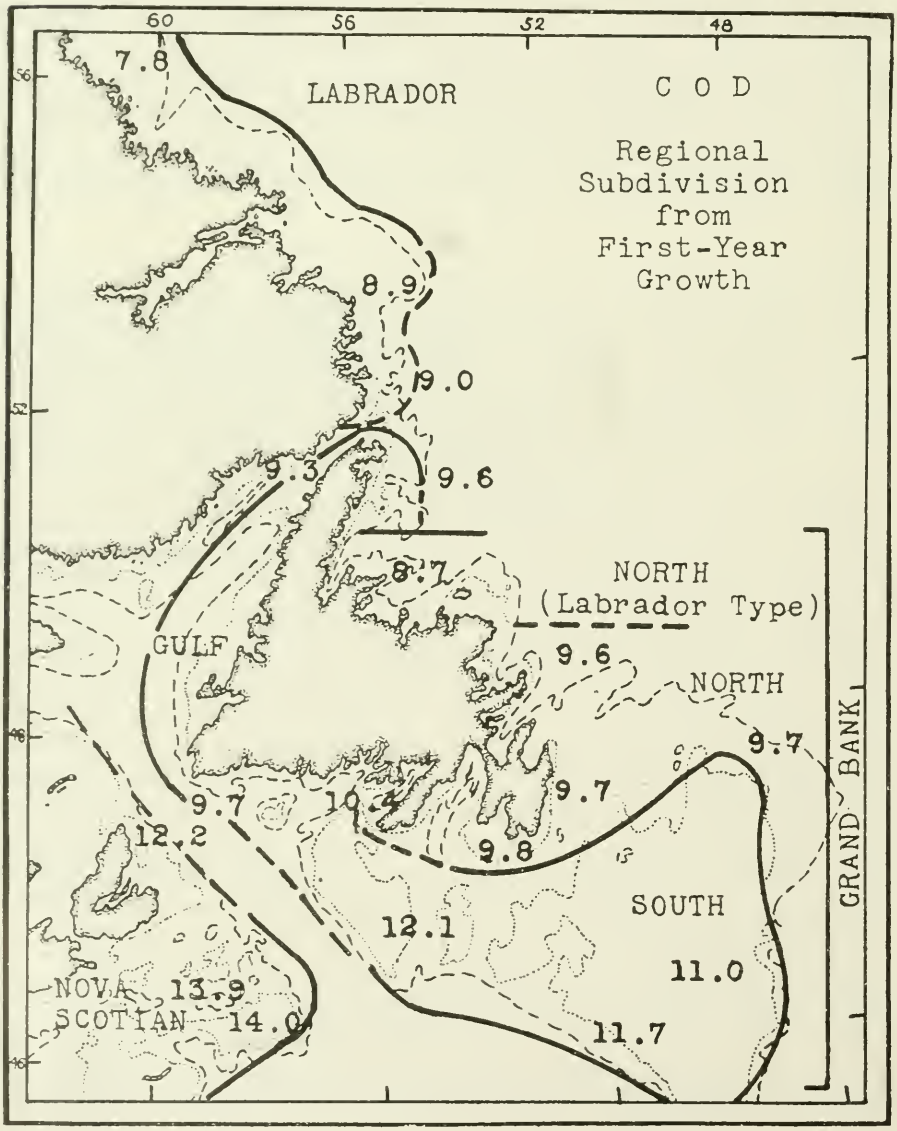
Local "Races" of Cod

It is usual to base the "racial" studies of fish upon the statistical demonstration of differences in the average numbers of vertebræ, fin rays, etc. Such work may be impeded by the difficulty of obtaining really representative material. A rapid method of making a first classification of the local cod stocks has been found. It is based on the fact that the impress of environment is clearly shown on the scales of the cod during the first year. Cod developing in a rather more favourable area, where the temperature of the water remains moderate or comparatively high for a considerable period of the year, make the best first year's growth. Conversely, cod developing in waters of low average temperature—e.g., off the Labrador coast—reach but a small size at the end of the first year. This characteristic is depicted on their scales. There are, in the case of northern Labrador codfish, fewer than eight growth-rings (sclerites) on the average in the first year zone of the scale. Further south, Grand Bank codfish produce an average of 9-10 (north bank) and 11-12 (south bank). (It has been deduced that it is cod of the north bank type which come inshore on the southeastern and eastern portions of the coast, since these inshore cod always have an average of about $9\frac{1}{2}$ first year sclerites). The Nova Scotian (or Western bank) cod experience still more favourable conditions and the average rises to from 12-$14\frac{1}{2}$. Off the Massachusetts coast it is still higher, probably around 20, although, since the scales are not so clearly marked as is the case further north, it is difficult to make an accurate estimate.

By use of this method it is possible to make a rapid first classification of the regional codfish stocks, and to form some idea, in the case of the inshore migrations of shoals, of the areas from which the latter have come. Tagging operations now being undertaken in various portions of the area will serve as a test of the extent of the reliability of the deductions which have been made. On the whole,

it appears to be adequate to make a preliminary subdivision of the area into four portions (Fig. 2) with the following cod stocks, which are indentifiable by using the method described:—

1. *Nova Scotian (Western Bank)* Cod, with an average of between 12 and 14½ first year sclerites.
2. *Grand Bank Cod*, with an average number of sclerites falling from 12 in the south to 9½ in the north.
3. *Gulf of St. Lawrence Cod* (including cod of the winter fishery in the south-west) with an average number of between 9 and 10 first year sclerites, and differentiated from Grand Bank cod by having a much slower growth rate in subsequent years of life.
4. *Labrador Cod*, with an average dropping from 9 sclerites at the level of the Straits of Belle Isle (where there is admixture with Gulf cod and possibly Bank cod) to below 8 at the level of Cape Harrigan.



Growth Rates.—Owing to the sharpness and comparatively long duration of winter conditions the scales of the codfish in the Newfoundland area show the annual zonation much more clearly than is the case in codfish of most other regions. It is therefore possible to make a comparatively accurate determination of age and of rate of growth. Of the four groups of cod mentioned above, that found on Grand bank exhibits the fastest growth rate. A normal curve of growth is shown, with a marked diminution of growth in the later years of life. This growth-rate also agrees with that derived from an examination of inshore cod in the southeast coastal region facing the bank. Labrador cod, Western (Nova Scotian) Bank cod, and Gulf cod, in the order named, show successive diminutions of growth rate as compared with Grand Bank cod, with the exception that old migrating cod, of approximately ten years of age and upwards, seem to penetrate these areas in certain numbers, and give rise to a marked upward swing in the appropriate curves of growth.

It may be of interest to mention at this point that it has been determined in the Newfoundland Laboratory that the relative quantity of Vitamin A in cod liver oils increases in proportion to increase in the age of the fish. This possibly implies a certain degree of accumulation in the livers. Being, on the whole, slow-growing and relatively old fish, the cod of Newfoundland yield a liver oil of extremely high Vitamin A potency. Especially is this so in the case of the Gulf cod (winter fishery) which, before they reach commercial size, are of high average age.

The Food of the Cod.—By making volumetric determinations of the average content of food in the stomachs of the cod, it has been found that the best feeding conditions occur on Grand bank, and the poorest on Labrador and in the Gulf of St. Lawrence area. There is a short period, just after the spawning season, when very large quantities of food are consumed. In the case of cod remaining on the banks, this is composed chiefly of lance. In the case of cod moving in to the coast it consists of caplin. After the period of heavy feeding and recuperation, the consumption of food drops off very markedly to the level of a more or less subsistence diet, chiefly of shrimps or crabs, according to area. The slow-growing cod of the Gulf area, while occasionally found to be feeding on herring, are seldom found to contain much food, and the species consumed (e.g., alligator-fish, rosefish, etc.) are of relatively low calorific value.

Age—Composition.—No violent fluctuations have been found to occur in the cod stocks of the area, so far as these investigations go. On the whole, the three year period under review has been one during which no general scarcity of cod occurred—in fact, cod, except perhaps in 1931, have been plentiful. As about six annual broods go to compose the bulk of the fish used commercially, fluctuations would appear to be very much smoothed down. Although, therefore, it is just possible that, in certain periods of years, cod may be rather more or less plentiful than usual, there is little reason to anticipate striking changes (other than those caused locally by the temporary unsuitability of water temperature). That, however, some annual broods of cod can be much more successful than others is shown by the following age analysis for Grand Bank cod:—

NUMBER PER 1,000

Year Brood	Year 1931	Year 1932	Year 1933
1929	.....	18	51
1928	124	117	110
1927	*185*	*195*	*173*
1926	102	90	137
1925	120	125	174
1924	*277*	*235*	*223*
1923	122	135	67
1922 etc.	70	85	65

The gradual length increase, with increasing age, of the more plentiful year classes affects the average size of the fish caught. This average size has been increasing since 1931 owing to the upgrowth of the plentiful 1924 class, which has, however, now reached the age at which the scope of migration appears to be considerably extended. As far as the inshore fishery is concerned little more may be expected to be seen of it.

Little of definitive value has yet emerged from the continuous study of the distribution of the eggs and fry of the cod. There is, however, a noteworthy correlation between the location of fry and the variation in the prevalent current systems from year to year. Some further correlation will in time probably be possible with the actual geographical distribution of the annual broods of cod when the latter are large enough to appear in the commercial catches.

Effect of Physical Conditions on the Distributions of Cod.—The outstanding cause of local manifestations of scarcity or plentifulness of cod is the pronounced tendency for sharp temperature fluctuations to occur. Evidence has been given above to support the conclusion that there are local races or recognizable groups of cod, each remaining in or near the locality of birth, at least till an advanced age is reached. Different groups will therefore live under, and adjust themselves to, different temperature conditions, and within each region there will probably be a narrow range of temperature variation within which cod will best succeed and therefore occur in the largest numbers. Thus these investigations have shown that there is no one such range of temperature within which cod will always occur in greatest numbers, but that there is such a range for each subregion. On Grand bank, in spring, there is a sharp line of differentiation to be drawn between water of below 0°C. and water half a degree or more above 0°C. Few cod can be caught at the former temperature, whilst large numbers may occur at the latter. Even in summer the optimum temperature for medium and large Grand Bank cod is a mere 3½°C. (although very young fish can be plentiful in water several degrees warmer than this figure). Grand Bank cod, in other words, are accustomed to life in very cold waters.

In the gulf of St. Lawrence and vicinity the optimum temperatures are much higher, the limiting temperature for the occurrence of cod being 12°C.

The continuous study of the physical conditions in the area, coupled with that of the varying degrees of occurrence of codfish at different levels on the banks and on different portions of the inshore area, is proving of value. It has been proved that the steam trawler operated from the laboratory can be aided

in her search for "paying loads" of fish on the banks by using the thermometer as a guide. It is also proving possible to connect the absence of fish on a certain portion of the coast with the prevalence of water much warmer or much colder than the optimum temperature for the region. Similarly, large runs of fish are nearly always obtained at around the optimum temperature. The demonstration of these facts renders feasible the making of forecasts of the probable nature of the runs of cod in various regions. Although no public forecasts have yet been issued, many private enquiries have been answered as to the more immediate prospects of the fishery on various parts of the coast. With the establishment of a system whereby weekly temperature reports could be received from stations spaced around the coast there seems to be no reason why information of very considerable value could not be broadcasted.

HADDOCK INVESTIGATIONS

No direct effort has been made to study the biology of the haddock which occurs (often in surprisingly great numbers) in the southern portion of the Grand Bank region. Some data have been collected incidentally during the cruises of the research vessel. Haddock fry have not yet been captured in quantities, but the locations of such as have occurred in the systematic plankton collections have been recorded. Medium and large haddock are confined in their distribution to southern Grand bank and St. Pierre bank, although occasional migrants occur inshore. While cod fishing the trawler frequently encounters enormous shoals of haddock and captures fifteen tons or more per day. When the temperature of the water is taken on such occasions it is invariably found to be between 5° and 9°C., i.e., too warm for codfish in abundance. A shift of a few miles to the northeast usually brings the vessel back over the colder water harbouring the cod shoals. The trawler skipper, an experienced fisherman, has thus come to regard his temperature readings as indispensable.

From a study of the scales of the haddock it has been found that the growth rate is excellent, approximating to that of Iceland haddock. It is especially good during the first three years of life, a fact which implies that the recuperative power of these grounds would be excellent if they were subjected to intensive fishing activities. Only about a couple of good broods sustain the large numbers to be found. Thus on Grand bank, in the three years under review, the 1927 and 1928 year classes have comprised the bulk of the population. On Banquereau the outstanding year classes have been those of 1928 and 1929. These broods are apparently causing an increase over the normal in the density of the stock, and it will be of interest to follow their subsequent history. All the indications point to excellent catches in 1934 and 1935.

FRENCH INVESTIGATIONS AT NEWFOUNDLAND AND GREENLAND IN 1931, 1932, 1933

If what is called in France the phenomenon of transgressions is exact, that is to say, if the whole mass of oceanic waters and not only certain regions where the movement, for different causes, is more important, like the region of the Gulf Stream, if all that mass is carried alternately northwards and southwards, there

is a cause for it. Among the influences which may contribute to this movement, the most important is the variation in temperature either from season to season or from year to year, which brings on as an unavoidable consequence variations of density in the mass of water and therefore slow displacements of the concerned molecules.

Analogous phenomena in meteorology must then be recognized and in the report for 1931 *(Revue des Travaux de l'Office des Pêches, Tôme V, fasc. 1)* study has been made of what meteorological conditions at any point in the region where an observatory could register daily the indispensable data of temperature, pressure and wind, might strengthen or weaken this thesis.

The influence of atmospheric phenomena on the surface water at least is certain. It even seems to affect the supply of polar water through two causes: first, by influencing the formation of the ice pack in winter, and by retarding or accelerating the melting and warming up in spring and summer, and second, by modifying the abundance of icebergs.

Acceleration in the descent of icebergs is connected with the frequency of moist depressions from the south and the barometric conditions of the year may furnish indications in this connection. The formation of the ice pack, its melting, and the warming up of the water are connected with temperature, and temperature conditions will throw some light on that point.

If the two factors, low pressure, and low temperature, which seem at first sight contradictory, do nevertheless co-exist, which is frequently observed, both influences will contribute to increase the polar outflow, giving a hydrological phase, to be characterized as *superabundant*. If one of the two factors occurs and the other is absent, there is a kind of compensation and the hydrological conditions will be *normal;* finally if both are deficient, the hydrological conditions will be *insufficient*.

Now the meteorological statistics in recent years and the hydrological investigations, since they have been undertaken, have agreed in their main features, which alone are of interest in the case of general phenomena of this range.

And, to conclude, the fisheries statistics show on the one hand a remarkable agreement between abundance of polar outflow and success of the French fishery, that is to say of that carried on on the southern limits of the Grand Bank or its southeastern limits, and, on the other hand, an agreement between a fishery failure in the same region and an insufficiency in the supply of polar water.

Such a remarkable fact deserves consideration. If at the southeastern extremity of the Banks, we are more affected than elsewhere by these fluctuations because we are on the limits of the domains of polar water and of cod, it is nevertheless very probable that the other fishing regions, especially the Gulf of St. Lawrence, the coasts of the Canadian Maritime Provinces, and the coasts of Newfoundland and Labrador must be equally interested in following from year to year these concomitant variations without concentrating on, or losing time in the study of minor local variations, which are lost in the main trend. From these observations may result, before very long, a general foresight sufficient for advising the fishermen of the value to them of shifting their activities in this direction or in that.

OBSERVATIONS MADE IN 1931 IN GREENLAND

In 1931, the French trawlers did not meet again at the southeastern edges of the Grand Bank, and at the southern end of Whale Deep, with the exceptional conditions they had found in 1929 and 1930. It was farther west, south of St. Pierre bank at a depth of 150 to 300 metres and south of Sable Island bank, at similar depths, that cod abounded, gathering into schools.

Between the two, from April to the end of June, the southern edges of Banquereau, from 80 to 100 metres, with a temperature close to 3°C. abounded with spawning cod, of a medium size, as is always the case with the fishes frequenting the Banquereau. Farther north and to the northeast, in shallow water of 60 metres and less, several groups of fishes about to spawn were found at temperatures from 2·5 to 2·9°C. Warmer water was close by, but cod, on the whole of small size, which occupied the shallow bottom, seemed to be attracted by the abundance of plankton, particularly of *Meganyctiphanes norvegica*, large quantities of which were found in the stomachs of captured fish.

With the coming of summer, that kind of fishing was discontinued; fish scattered and the French trawlers proceeded to Greenland where the fishing season was late and, scarcely extended from August to October.

Commandant Beaugé personally followed the fishing operations carried on by the trawlers during the spring on the Banquereau and made some observations of importance, especially from the hydrographical standpoint, which gave the result that the whole cartography of the southern part of Banquereau should be altered. The southeastern extremity is very inaccurately represented on the present charts. Owing to the remarkable variations of the currents in that region, it seems impossible to rectify the chart without having a very thorough survey, based on well localized buoys, firmly anchored on the bottom.

Having returned to France about the middle of June, he left again for Greenland in September and October and returned in November. He was thus present at the close of the trawler fishing in Greenland.

In July, on the arrival of the vessels, the situation was unfavourable and showed, as stated, a lagging in the warming up of the waters compared with the previous years, which coincides, by the way, with the French theory of transgressions and their getting later and later in relation to seasonal warming during the years 1930 to 1933.

On the 9th of July, at latitude 63° to 64°, the temperature at 50 metres was only from 0·7° to 1°C. A warm layer, not very thick (its temperature 5° at 25 metres), pressed close to the banks. Below, the coastal polar water was 1° at 75 metres. This cold layer was still extending during the summer. On the 28th of August, it was 1·7° at longitude 53° at 50 metres, whereas on the 19th of July, 3° had been observed at that point. This temperature was 2° to 3° lower than that observed in 1929.

It was farther north that moderately warm slope water (33 to 34 in salinity) driven by the warm transgression, reached the slopes of the outer banks. At latitude 62° on the 9th of July, it was 4·7° at 100 metres and 4·2° at 200 metres. At the same time, when the southern banks at less than 100 metres were under cold water, the Store Hellefiske began to experience more than 3°

at 80 metres. This temperature would remain favourable until the 25th of October, although cooling would make itself felt beginning the 30th of September.

An important hydrological section made by the *Ville d'Ys* between Newfoundland and Greenland, compared with that made in 1929 on board the *Sainte-Jeanne d'Arc* showed a decided increase in the polar outflow between the two years. The water mass with a temperature above 4° had much decreased; the reduced transgression had been blocked on the right side, that is to say to the northeast of the section, while the water had grown cold to the south towards Newfoundland, owing to a marked influx of polar water.

From the fishery standpoint, the Greenland catches showed an average decrease of 30 per cent from the previous year. Fish kept in preference in midwater where plankton abounded, with sand-eels. Contrary to what had occurred in 1929, the cod had not got rid of their spawn when the fishermen arrived, but on the contrary spawned during the summer and even up to October and on the outer banks.

What was likewise observed was a considerable concentration at the beginning of October on the northern banks, followed by a complete exodus or running away of the fish, apparently southward. The two movements: that from the south to the north that we had already ascertained in 1930 by the discovery on the Store Hellefiske of cod bearing French hooks in their mouths, when the French sailboats were at Fyllas; and then that from the north to the south with the coming of the winter, have thus been established. They occur at various times depending upon when the water warms up and this year, after a decided delay in the former movement, it seems that the latter was about three weeks early. To sum up, fishing was curtailed at both ends. But it was nevertheless very productive while the fish were in the region frequented by our fishermen.

INVESTIGATIONS CARRIED ON IN 1932

At Newfoundland, the standard section made by the *Ville d'Ys* at 45° North Latitude, across the Banks, placed the year 1932 among the average years. The details of these investigations may be found in *La Revue des Travaux de l'Office des Pêches, Tome VI, fasc. 1er.*

The details of the temperatures and salinities obtained in June in a sufficiently complete manner, show the conditions as having been similar to those of normal years at Newfoundland. The warm transgressions took place along three main axes: one at the right side of the Laurentian channel on the slopes of the St. Pierre bank, the second one south of Green bank, between that bank and Whale bank, the third one, from the southern edges of the Grand bank towards the northeast. The last is always the most important one. Water at 4° already reached in June latitude 46° on longitude 49° 30′, leaving the "Platier" with cold water.

In spring, fish abounded on the Edges in fairly deep water (100 metres and rather more). At the end of March and at the beginning of April, the warm transgression reached the slope of St. Pierre bank and fishing was excellent at latitude 45° and longitude 55° 30′ (temperature 3° at 190 metres). At

Banquereau, the temperatures were irregular (2·5° at 150 metres, cold at 65 metres) and fish were not so abundant. In contrast, the water south of Sable island was favourable from 60 to 100 metres deep.

It chanced that an isolated report gave the information that starting the 2nd of June, fish abounded on the edges of the Grand bank, from 43° 30′ to 45° North, as well as on the banks themselves up to latitude 46° 50′ and as far as the Virgin rocks. But the French fishermen were concentrated at the "Platier" in a not very favourable region (to which they are restricted for lack of bait elsewhere) and they went early to Greenland to have poor fishing there.

An important discovery took place in August. This was the demonstration of an extraordinary abundance of big cod on the eastern Edges from 45° to 45° 30′ as well as in deep water (more than 100 metres). This condition was repeated during succeeding summers on the declivities of the slope and as deep as 350 metres and more (450 metres in 1934).

Since learning at Greenland the use of "diabolos," trawlers have begun to attempt the broken and often rough bottoms which are found at latitude 45° between longitude 50° and 52°. The fish were found again in that location in 1933 and 1934. Fishing was good there and the cod of good size, although scattered and not gathered in schools. At the "Platier," cod abounded in the fall but they were nevertheless of small size. It was the 1926 class, which had been predominating for the previous three years and had not yet reached good marketable size.

At Greenland, a section made by the *Ville d'Ys* between the strait of Belle Isle and the southwestern banks of Greenland showed an increase in the displacement to the northeast of the 4° isotherm. A large mass at a temperature close to 0° extended from 30 metres to the bottom between latitude 63° and 64° near longitude 53°. Near Newfoundland, the cold mass increased; temperatures less than 1° were very important. A powerful cold wedge was thrust in at about 100 metres depth between latitude 55° and 56°, longitude 54°. Vertical uniformity in temperature at 3° was found at the northern limit of that region.

On the southern banks, temperatures were still lower than those of the previous year and they grew colder from the beginning of July to the end of August through the late arrival of the polar outflow. It seems that at the beginning of the season, the eastern edges of the coastal plateaus were covered with fairly warm water (3·5°) which grew cold during summer with the late arrival of polar water, the latter passing around Farewell to then flow back northward and block the mouths of the fjords, at least at the surface and to a depth ranging from 25 to 50 metres.

There were no ice-floes in May at Farewell, very few in June as far as Fyllas, while at the end of July they abounded from latitude 61° to 63°. On the other hand, the southern banks were surprisingly long in growing warm. On the 6th of November, at latitude 63° 48′ and longitude 52° 30′ when the outer temperature was below 0°, the surface water was above 5° and it was 7° at 70 metres in depth. Farther south, at Fiskerness, at 63° 25, on the edges, in a depth of 110 metres, 10° was observed. In July it was 0° at that depth, in that place.

It was seen how much the warm transgression had been delayed, and it was then understood that, if the phenomenon had already started the previous

winter, although on a smaller scale, a comparatively high temperature in the vicinity of the inner ridge of the outer banks could have been found before the arrival of the polar outflow. It would have been a remnant of the previous warming. This polar water was as if exhausted, from the standpoint of plankton nutrition and it was not surprising that it should have been little appreciated by cod.

The marking of fish carried on at Greenland and Iceland confirms the remarks already made concerning the shifting of large quantities of cod to more favourable regions, particularly to the south of Iceland, and this helps us to understand the remarkable decrease in fish, which was demonstrated at Greenland.

INVESTIGATIONS IN 1933

All the reports made that year by the trawlers, the investigator not having been able to make the trip, owing to the fitting out of the *Président Théodore Tissier*, confirm the observations made in 1932. The Newfoundland region had become very favourable for trawlers and even for sail-boats. On the other hand, Greenland had become less and less satisfactory.